भारतीय मानक
Indian Standard

IS 802 (Part 1 / Sec 1) : 2015
(Reaffirmed 2020)

शिरोपरि प्रेषण लाईन टावरों में संरचना इस्पात उपयोग — रीति संहिता

भाग 1 सामग्री, भार और अनुमत प्रितबल
अनुभाग 1 सामग्री और भार

(चौथा पुनरीक्षण)

Use of Structural Steel in Overhead Transmission Line Towers — Code of Practice

Part 1 Materials, Loads and Design Strengths
Section 1 Materials and Loads

(Fourth Revision)

ICS 91.080.10

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Structural Engineering and Structural Sections Sectional Committee, CED 07

FOREWORD

This Indian Standard (Part 1/Sec 1) (Fourth Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Structural Engineering and Structural Sections Sectional Committee had been approved by the Civil Engineering Division Council.

Transmission towers are tall structures, usually steel lattice towers, used to support overhead power lines. Transmission line towers are key infrastructural components. The standards under IS 802 series have been formulated with a view to establish uniform practices for design, fabrication, inspection and testing of overhead transmission line towers.

This standard (Part 1/Sec 1) is a part of a series of standards thus formulated and covers requirements in regard to material, loads and design strengths apart from other relevant design provisions. The other parts in the series are:

Part 2 Fabrication, galvanizing, inspection and packing

Part 3 Testing

Part 4 Requirements for latticed switchyard structures (*under formulation*)

Part 5 Requirements for tall river crossing towers (*under formulation*)

This standard IS 802 (Part 1) was first published in 1967 and subsequently revised in 1973, 1977 and 1995. The standard in its third revision was split in two sections, namely; Section 1 Materials and loads, and Section 2 Permissible stresses.

Some of the major modifications made in this standard (Part 1/Sec 1) in this revision are:

a) Provision for use of structural steel tubes has been included.
b) Material requirements for bolts and nuts have been modified.
c) Light angle towers for use in straight runs with line deviation >5° but <15° and medium angle towers (15° to 30°) have been included.
d) Drag co-efficient for evaluating wind load on towers have been stipulated for different sections (such as angles and circular sections).
e) Load combination for sag tension of conductor and ground wire / optical groundwire (OPGW) and for climate loads have been modified.
f) Narrow front wind load has been identified as an applicable load for suspension towers.
g) Transverse load conditions have been modified.
h) Vertical erection loads in safety requirement have been modified.
j) Wind load consideration in longitudinal load calculation for security requirement has been redefined.

As transmission line towers are comparatively light structures and also that the maximum wind pressure is the chief criterion for the design, the concurrence of earthquake and maximum wind pressure is unlikely to take place. However in earthquake prone areas, the design of towers/foundations shall be checked for earthquake forces corresponding to nil wind and minimum temperature in accordance with IS 1893 (Part 1) : 2002 ‘Criteria for earthquake resistant design of structures: Part 1 General provisions and buildings (*fifth revision*)’.

Ice loadings on towers and conductors/ground wire/OPGWs for lines located in the mountainous regions of the country subjected to snow fall, may be taken into account on the basis of available meteorological data both for ice with wind and without wind.

While formulating the provisions of this Code, it has been assumed that structural connections are through bolts only.

(*Continued on third cover*)

Indian Standard

USE OF STRUCTURAL STEEL IN OVERHEAD TRANSMISSION LINE TOWERS — CODE OF PRACTICE

PART 1 MATERIALS, LOADS AND DESIGN STRENGTHS
Section 1 Materials and Loads

(Fourth Revision)

1 SCOPE

1.1 This standard (Part 1/Sec 1) stipulates materials and loads to be adopted in the design of self-supporting steel lattice towers (using angles/circular hollow sections) for overhead transmission lines.

1.2 Design strengths and other design parameters are covered in IS 802 (Part 1/ Sec 2).

1.3 Provisions on fabrication including galvanizing, inspection and packing, etc, and testing of transmission line towers have been covered in IS 802 (Part 2) and IS 802 (Part 3), respectively.

1.4 Provisions for loads and design strengths for latticed switch yard structures are covered in IS 802 (Part 4) (*under preparation*).

1.5 Provisions for loads and design strengths for tall river crossing towers shall be covered in a separate standard (*under formulation*).

1.6 This standard does not cover guyed towers.

2 REFERENCES

The standards listed in Annex A contains provisions, which through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standard indicated at Annex A.

3 STATUTORY REQUIREMENTS

3.1 Statutory requirements as laid down in the *The Indian Electricity Rules*, 2005 or by any other statutory authority applicable to such structures as covered in this standard shall be satisfied. However, only the probabilistic concept, that is, use of safety factors for loads and materials shall be adopted instead of the factor of safety concept.

3.2 In addition to compliance with local and provincial byelaws, fire and safety laws [as per the provisions of IS 5613 (Part 2/Sec 2)] and civil aviation requirements/electricity rules shall be applicable to such structures, as specified by the purchaser/end user shall be complied with.

4 TERMINOLOGY

For the purpose of this standard the following definitions shall apply.

4.1 Return Period — The number of years, reciprocal of which gives the probability of extreme wind exceeding a given wind speed in any one year.

4.2 Reliability — Reliability of a transmission system is the probability that the system would perform its function/task under the designed load condi-tions for a specified period. In simple terms, the reliability may be defined as the probability that a given item will indeed survive a given service environment and loading for a prescribed period of time.

4.3 Security — The ability of a system to be protected from any major collapse such as cascading effect, if a failure is triggered in a given component. Security is a deterministic concept as opposed to reliability, which is probabilistic.

4.4 Safety — The ability of a system not to cause human injuries or loss of life. It relates, in this standard, mainly to protection of workers during construc-tion and maintenance operations.

4.5 Tangent Tower — Also known as 'suspension tower' or 'straight line tower'. Conductors on these towers are supported by means of I-strings, V-strings, or a combination of I and V strings.

4.6 Angle Tower — These are used at locations where there is same angle of deviation. These towers are further classified based on different deviation angles. These towers are also known as 'tension tower' as conductors are generally supported with tension insulators on these towers.

4.7 Suspension Insulator String — I, V or Y type insulator string suspended on tangent/suspension/ straight-run tower. On this string, conductor is suspended from a cross-arm.

4.8 Tension Insulator String — This string is used on tension/section/angle/dead end towers. It is provided on both side of tower in the direction of conductor.

5 MATERIALS

5.1 Structural Steel

The tower members including cross arms shall be of structural steel conforming to any of the grade, as appropriate, of IS 2062 or steel tubes for structural purposes of IS 1161.

5.1.1 Hot rolled structural steels (cold formed only for hollow circular sections) with known properties conforming to other national and international standards may also be used subject to the approval of the purchaser/end user.

5.1.2 In addition to structural angle sections, tubes conforming to IS 1161 enabling other structural sections and materials in PPP with appropriate engineered property can also be used.

NOTE — Pipes used for oil transmission shall not be used as structural sections as per this standard.

5.2 Bolts

5.2.1 Bolts for tower connections shall conform to IS 12427.

5.2.2 Foundation bolts shall conform to IS 5624.

5.2.3 Step bolts shall conform to IS 10238.

5.3 Nuts

Nuts shall conform to IS 14394. The mechanical properties shall conform to property Class 5 or Class 8 as the case may be.

5.4 Washers

5.4.1 Washers shall conform to IS 2016 with thickness as required based on connection details. Spring washers shall conform to Type B of IS 3063. Heavy washers shall conform to IS 6610.

5.4.2 Washers to be used with high strength bolts and nuts shall conform to IS 6649.

5.5 Galvanization

5.5.1 Tower members shall be galvanized in accordance with the provisions of IS 4759.

5.5.2 Threaded fasteners shall be galvanized to conform to the requirements of IS 1367 (Part 13).

5.5.3 Spring washers shall be electro-galvanized as per grade B of IS 1573 as and plain washers shall be hot dip galvanized as per service Grade 4 of IS 4759 or electro galvanized as per service Grade 3 of IS 1573 as specified by the purchaser/end user.

5.6 Other Materials

Other materials used in the construction of the tower shall conform to appropriate Indian Standards, wherever available.

6 TYPES OF TOWERS

6.1 The selection of the most suitable types of tower for transmission lines depends on the actual terrain through which the line traverses. Any combination of the following types of towers is generally suitable for most of the lines:

a) *Suspension towers (with I or V or Y suspension insulator strings)*:

1)	Tangent towers (0°) with suspension string	:	To be used on straight runs only
2)	Intermediate towers (0° to 2°) with suspension string	:	To be used on straight runs and upto 2° line deviation
3)	Light angle towers (0° to 5°) with suspension string	:	To be used on straight runs and upto 5° line deviation

NOTE — In the selection of suspension tower either (b) above or a combination of (a) and (c) may be followed.

b) *Tension towers*:

1)	Small angle towers (0° to 15°) with tension string	:	To be used for line deviation from 0° to 15°
2)	Medium angle towers (0° to 30°) or (15° to 30°) with tension string	:	To be used for line deviation 0° to 30° or 15° to 30°.
3)	Large angle towers (30° to 60°) with tension string	:	To be used for line deviation from 30° to 60°.
4)	Dead-end towers with tension string	:	To be used as dead-end (terminal) tower or anchor tower.
5)	Large angle and dead-end towers with tension string	:	To be used for line deviation from 30° to 60° or for dead-ends.

NOTE — In the selection of tension towers either (5) or a combination of (3) and (4) may be followed.

6.2 The angles of line deviation specified in **6.1** are for the design span. The span may, however, be increased up to an optimum limit with reducing angle of line deviation, if adequate ground and phase clearances are available.

7 RELIABILITY CONSIDERATIONS

7.1 Transmission lines shall be designed for the reliability levels given in Table 1. These levels are expressed in terms of return periods in years of climatic (wind) loads. The minimum yearly reliability P_s, corresponding to the return period, T is expressed as:

$$P_s = (1 - 1/2T)$$

Table 1 Reliability Levels of Transmission Lines
(*Clause* 7.1)

Sl No.	Description	Reliability Levels		
		1	2	3
(1)	(2)	(3)	(4)	(5)
i)	Return period of design loads, in years, T	50	150	500
ii)	Yearly reliability, P_S	$1–10^{-2}$	$1–10^{-2.5}$	$1–10^{-3}$

7.2 Reliability level 1 shall be adopted for EHV transmission lines upto 400 kV class.

7.3 Reliability level 2 shall be adopted for EHV transmission lines above 400 kV class.

7.4 Reliability level 3 shall be adopted for tall river crossing towers and special towers, although these towers are not covered in this standard.

8 WIND EFFECTS

8.1 Basic Wind Speed, V_B

Figure 1 shows basic wind speed map of India as applicable at 10 m height above mean ground level for the six wind zones of the country. Basic wind speed V_B is based on peak gust velocity averaged over a short time interval of about 3 s, corresponds to mean heights above ground level in an open terrain (Category 2) and have been worked out for a 50 years return period [*see* IS 875 (Part 3)].

Basic wind speeds for the six wind zones (*see* Fig. 1) are:

Wind Zone	*Basic Wind Speed*, V_B m/s
1	33
2	39
3	44
4	47
5	50
6	55

NOTES

1 Reference may be made to IS 875 (Part 3) for basic wind zone maps.

2 In case the line traverses on the border of different wind zones, the higher wind speed may be considered.

8.2 Meteorological Reference Wind Speed, V_R

It is the extreme value of wind speed over an aver-aging period of 10 min duration and is to be calculated from basic wind speed, V_B by the following relationship:

$$V_R = V_B / K_0$$

where, K_0 is a factor to convert 3 s peak gust speed into average speed of wind during 10 min period at a level of 10 m above ground. K_0 may be taken as 1.375.

8.3 Design Wind Speed, V_d

Reference wind speed obtained in **8.2** shall be modified to include the following effects to get the design wind speed:

a) Risk coefficient, K_1, and
b) Terrain roughness coefficient, K_2.

It may be expressed as follows:

$$V_d = V_R . K_1 . K_2$$

8.3.1 *Risk Coefficient, K_1*

Table 2 gives the values of risk coefficients K_1 for different wind zones for the three reliability levels.

Table 2 Risk Coefficient K_1 for Different Reliability Levels and Wind Zones
(*Clause* 8.3.1)

Sl No.	Reliability Level	Co-efficient, K_1 for Wind Zones					
		1	2	3	4	5	6
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	1	1.00	1.00	1.00	1.00	1.00	1.00
ii)	2	1.08	1.10	1.11	1.12	1.13	1.14
iii)	3	1.17	1.22	1.25	1.27	1.28	1.30

8.3.2 *Terrain Roughness Coefficient, K_2*

Table 3 gives the values of coefficient K_2 for the three categories of terrain roughness (*see* **8.3.2.1**) corresponding to 10 min averaged wind speed.

Table 3 Terrain Roughness Coefficient, K_2
(*Clause* 8.3.2)

Terrain Category	**1**	**2**	**3**
Coefficient, K_2	1.08	1.00	0.85

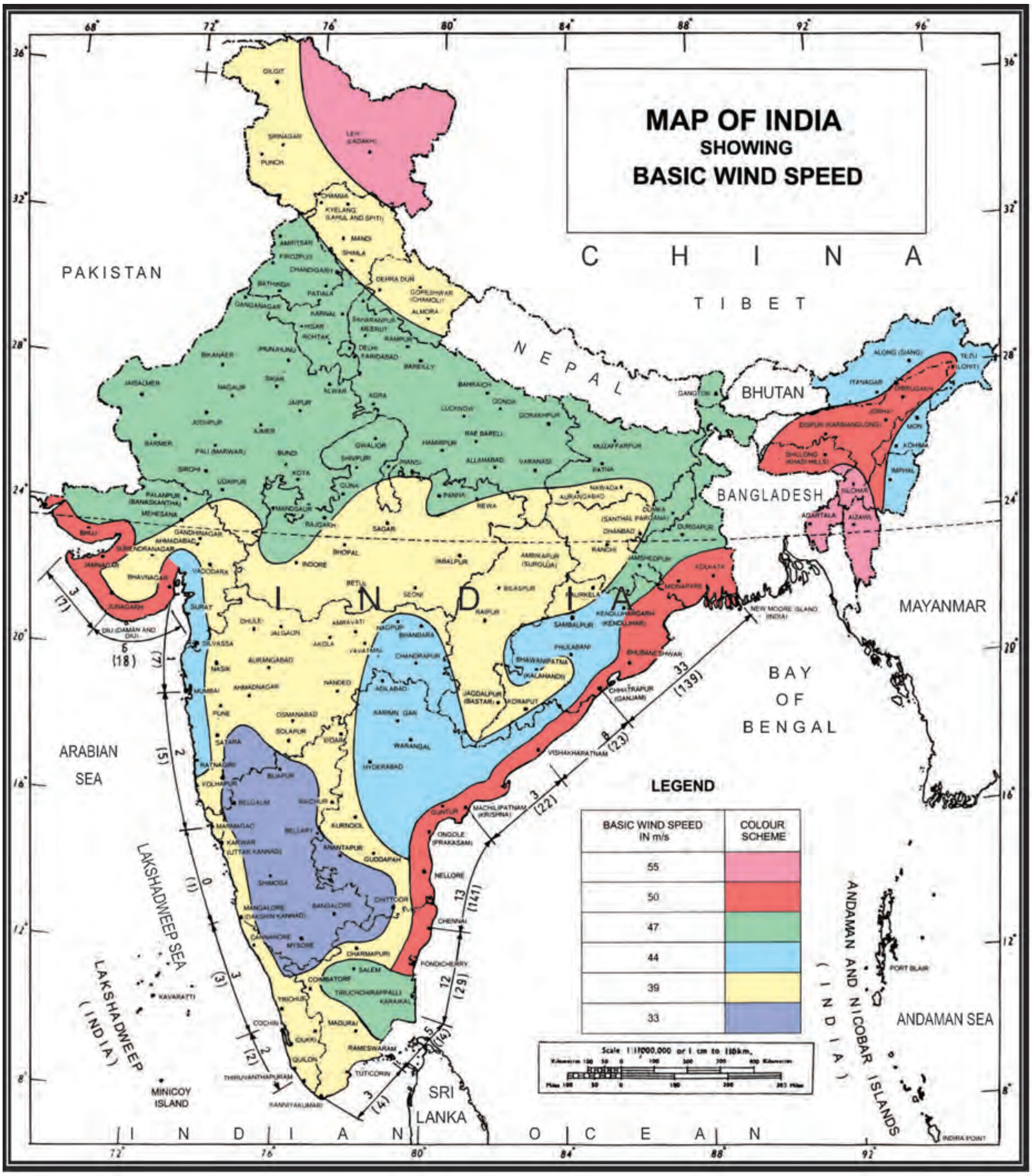
NOTE — For lines encountering hills/ridges, the value of K_2, for a given terrain shall be changed to next higher value of K_2.

8.3.2.1 *Terrain categories*

a) *Category* 1 — Exposed open terrain with few or no obstruction and in which the average height of any object surrounding the structure is less than 1.5 m.

NOTE — This category includes open seacoasts, open stretch of water, deserts and flat treeless plains.

b) *Category* 2 — Open terrain with well scattered obstructions having height generally



Based upon Survey of India Outline Map printed in 1993.

The territorial waters of India extend into the sea to a distance of twelve nautical miles measured from the appropriate base line.
The boundary of Meghalaya shown on this map is as interpreted from the North-Eastern Areas (Reorganisation) Act, 1971, but has yet to be verified.
Responsibility for correctness of internal details shown on this map rests with the publisher.
The state boundaries between Uttaranchal & Uttar Pradesh, Bihar & Jharkhand and Chhatisgarh & Madhya Pradesh have not been verified by Governments concerned.

FIG. 1 BASIC WIND SPEED IN m/s (BASED ON 50-YEARS RETURN PERIOD)

between 1.5 m and 10 m.

NOTE — This category includes normal country sides with very few obstacles.

c) *Category* 3 — Terrain with numerous closely spaced obstructions

NOTE — This category includes built up areas and forest areas.

8.4 Design Wind Pressure, P_d

The design wind pressure on towers, conductors and insulators shall be obtained by the following

relationship:

$$P_d = 0.6\ V_d^2$$

where

P_d = design wind pressure, in N/m²; and
V_d = design wind speed, in m/s.

8.4.1 Design wind pressures, P_d for the three reliability levels and pertaining to six wind zones and the three terrain categories have been worked out and given in Table 4.

9 WIND LOADS

9.1 Wind Load on Tower

9.1.1 In order to determine the wind load on tower, the tower is divided into different panels. These panels should normally be taken between connecting points of the legs and bracings. For square/rectangular lattice tower, the wind load for wind normal to the face of tower, on a panel height of '*h*' applied at the centre of gravity of the panel is:

$$F_{wt} = P_d\ (1 + 0.2 \sin^2 2\theta)\ (A_{eL} * C_{dtL} * \cos^2\theta + A_{eT}\ C_{dtT} \sin^2\theta)\ G_T$$

To calculate wind loads separately in transverse and longitudinal directions, above formula can be further simplified in two components as follows:

Component of $\frac{1}{2}F_{wt}$ in:

Transverse direction

$$F_{wt\ TRANS} = P_d * (1 + 0.2 \sin^2 2\theta)\ (A_{eT} * C_{dtT} * \sin\theta)\ G_T$$

Longitudinal direction

$$F_{wt\ LONGI} = P_d * (1 + 0.2 \sin^2 2\theta)\ (A_{eL} * C_{dtL} * \cos\theta)\ G_T$$

where

F_{wt} = wind load, in N;

$F_{wt\ TRANS}$ = component of wind load (F_{wt}) in transverse direction, in N;

$F_{wt\ LONGI}$ = component of wind load (F_{wt}) in longitudinal direction, in N

P_d = design wind pressure, in N/m²;

θ = angle of incidence of the wind direction with the perpendicular to longitudinal face of the tower (*see* Fig. 2);

C_{dtL}, C_{dtT} = drag coefficients respectively for longitudinal and transverse face for panel under consideration against which the wind is blowing. C_{dtL}, C_{dtT} for different solidity ratio are given in Table 5;

Solidity ratio is equal to the effective area (projected area of all the individual elements) of a frame normal to transverse and longitudinal directions divided by the area enclosed by the boundary of the frame normal to the transverse and longitudinal directions;

A_{eL}, A_{eT} = total net surface area of the legs and bracings including cross arm members and redundant of the panel projected normal to the longitudinal and transverse faces of the panel, in m². (The projections of the bracing elements of the adjacent faces and of the 'plan' and 'hip' bracing members may be neglected while determining the projected surface of a windward face);

γ = single circuit horizontal configuration towers, a part of tower frame above waist level which is not shielded by the windward face shall be taken separately for wind calculation of tower; and

G_T = gust response factor depending upon terrain category and height of C.G. of panel above ground level. Values of G_T for the three terrain categories are given Table 6.

Table 4 Design Wind Pressure P_d, in N/m²
(*Clause* 8.4.1)

Sl No.	Reliability Level	Terrain Category	Design Wind Pressure, P_d for Wind Zones					
			1	2	3	4	5	6
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
i)	1	1	403	563	717	818	925	1 120
		2	346	483	614	701	793	960
		3	250	349	444	507	573	694
ii)	2	1	470	681	883	1 026	1 182	1 455
		2	403	584	757	879	1 013	1 248
		3	291	422	547	635	732	901
iii)	3	1	552	838	1 120	1 319	1 516	1 892
		2	473	719	960	1 131	1 300	1 622
		3	342	519	694	817	939	1 172

9.1.2 In case of horizontal and delta configuration towers, outer and inner faces countering the wind should be considered separately for the purposes of calculating wind load on the tower, as shown in Fig. 2.

9.2 Wind Load on Conductor and Ground Wire/ OPGW

The load due to wind on each conductor and ground-wire normal to the line applied at supporting point shall be determined by the following expression:

$$F_{wc} = (P_d * \sin^2\Omega).L\ .\ d\ .\ G_c\ .\ C_{dc}$$

where

F_{wc} = wind load, in N;
P_d = design wind pressure in N/m²;
L = wind span, in m;
d = diameter of conductor/groundwire/OPGW, in m;
C_{dc} = drag Coefficient which is 1.0 for conductor and 1.2 for groundwire/OPGW;
G_c = gust response factor which takes into account the turbulence of the wind and the dynamic response of the conductor. Values of G_c are given in Table 7 for the three terrain categories and the average height of the conductor/ground wire/OPGW above the ground; and
$\sin^2\Omega$ = angle between wind direction and conductor/earthwire/OPGW. This value is to be considered maximum of $\sin^2\Omega1$, $\sin^2\Omega$ and $\sin^2\Omega$ (*see* Fig. 2) and to be applied on total wind span for calculating wind load on wire. This value of $\sin^2\Omega$ is considering the deviation angle of tower (Maximum = Φ and Minimum = 0°) to arrive at maximum possible wind load on wire.

9.2.1 The total effect of wind on bundle conductors shall be taken equal to the sum of the wind load on sub-conductors without accounting for a possible masking effect of one of the sub-conductors on another.

9.3 Wind Load on Insulator Strings

9.3.1 Wind load on insulator strings shall be determined from the attachment point to the centre-line of the conductor in case of suspension tower and up to the end of clamp in case of tension tower, in the direction of wind as follows:

Table 5 Drag Coefficient, C_{dt} for Tower
(*Clause* 9.1.1)

Sl No.	Solidity Ratio Φ	Force Coefficient, C_t		
		Flat Sided Members	Circular Sections	
			Sub-Critical Flow ($D\bar{V}_d < 6$ m²/s)	Super Critical Flow ($D\bar{V}_d \geq 6$ m²/s)
(1)	(2)	(3)	(4)	(5)
i)	0.1	1.9	1.2	0.7
ii)	02	1.8	1.2	0.8
iii)	0.3	1.7	1.2	0.8
iv)	0.4	1.7	1.1	0.8
v)	0.5	1.6	1.1	0.8
vi)	0.75	1.6	1.5	1.4
vii)	1.00	2.0	2.0	2.0

NOTES
1 Linear interpolation between the values is permitted.
2 Drag coefficient takes into account the shielding effect of wind on the leeward face of the tower. However, in case the bracing on the leeward face is not shielded from the windward face, then the projected area of the leeward face of the bracing should also be taken into consideration

Table 6 Gust Response Factor for Towers (G_T) and for Insulators (G_i)
(*Clauses* 9.1.1 *and* 9.3)

Sl No.	Height Above Ground	Values of G_T and G_i for Terrain Categories		
		1	2	3
(1)	(2)	(3)	(4)	(5)
i)	Up to 10	1.70	1.92	2.55
ii)	20	1.85	2.20	2.82
iii)	30	1.96	2.30	2.98
iv)	40	2.07	2.40	3.12
v)	50	2.13	2.48	3.24
vi)	60	2.20	2.55	3.34
vii)	70	2.26	2.63	3.46
viii)	80	2.31	2.69	3.58

NOTES
1 Intermediate values may be linearly interpolated.
2 See **12.1.2.2** (b) for G_T in narrow front wind condition.

$F_{wiTRANS} = P_d \,.\, A_i \,.\, G_i \,.\, C_{di} \,.\, \cos\theta$ … in transverse direction,

$F_{wiLONGI} = P_d \,.\, A_i \,.\, G_i \,.\, C_{di} \,.\, \sin\theta$ … in longitudinal direction,

where

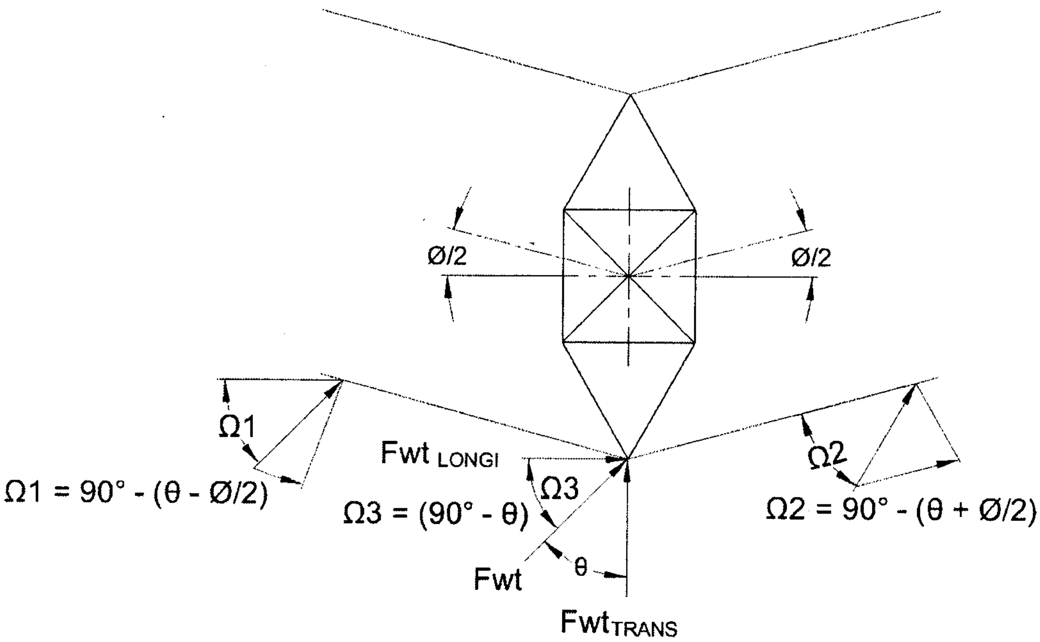
F_{wi} = wind load, in N;
$F_{wi\ TRANS}$ = component of wind load (F_{wi}) in transverse direction, in N;
$F_{wi\ LONGI}$ = component of wind load (F_{wi}) in longitudinal direction, in N;
P_d = design wind pressure, in N/m²;
A_i = 50 percent area of insulator string in m² projected on a plane which is parallel to the longitudinal axis of the insulator string;
G_i = gust response factor depending upon terrain category and height of insulator attachment above ground. Values of G_i for the three terrain categories are given in Table 6;
C_{di} = drag coefficient of insulator is taken as 1.2; and
θ = angle of incidence of the wind direction with the perpendicular to longitudinal face of the tower (*see* Fig. 3).

9.3.2 In case of multiple strings including V-strings, no masking effect shall be considered.

10 TEMPERATURE EFFECTS

10.1 General

The temperature range varies for different localities under different diurnal and seasonal conditions. The absolute maximum and minimum temperature which may be expected in different localities in the country



NOTES

1 The unbalanced tension due to different angles (Φ1 and Φ2) between wind direction and conductor on both spans of tower is to be neglected.

2 The average height will be taken up to the clamping point of conductor/groundwire/OPGW on tower less two-third the sag at minimum temperature and no wind.

FIG. 2 COMPONENTS OF WIND LOAD UNDER OBLIQUE WIND CONDITION

are indicated on the map of India in Fig. 4 and Fig. 5, respectively. The temperatures indicated in these maps are the air temperatures in shade. These may be used for assessing the temperature effects.

10.2 Temperature Variations

10.2.1 The absolute maximum temperature may be assumed as the higher adjacent isopleth temperature shown in Fig. 4.

10.2.2 The absolute minimum temperature may be assumed as the lower adjacent isopleth temperature shown in Fig. 5.

10.2.3 The average everyday temperature shall be 32°C anywhere in the country, except in regions experiencing minimum temperature of –5°C or lower (*see* Fig. 4), where everyday temperature may be taken as 15°C or as specified by the purchaser/end user.

10.2.4 The maximum conductor temperature may be obtained after allowing increase in temperature due to radiation and heating effect due to current, etc, over the absolute maximum temperature given in Fig. 3. The tower may be designed to suit the conductor temperature of 85°C (*Max)* for ACSR (aluminium conductor steel reinforced) and 95°C (*Max)* for AAAC (all aluminium alloy conductor). These values are only for general guidelines and depending on the properties of conductor different temperature value may be considered. The maximum temperature of ground wire/ OPGW exposed to sun may be taken as 53°C.

10.3 Sag Tension

Sag tension calculation for conductor and ground wire/ OPGW shall be made in accordance with the relevant provisions of IS 5613 (Part 2/ Sec 1) for the following combinations:

a) 100 percent design wind pressure after accounting for drag coefficient and gust response factor at everyday temperature [(P_d) for transverse wind and (P_d* $\sin^2\Omega$) for oblique wind],
b) 75 percent design wind pressure after accounting for drag coefficient and gust response factor at everyday temperature, and
c) 36 percent design wind pressure after accounting for drag coefficient and gust response factor at minimum temperature.

11 LOADS ON TOWER

11.1 Classification of Loads

Transmission lines are subjected to various loads during their lifetime. These loads are classified into three distinct categories, namely,

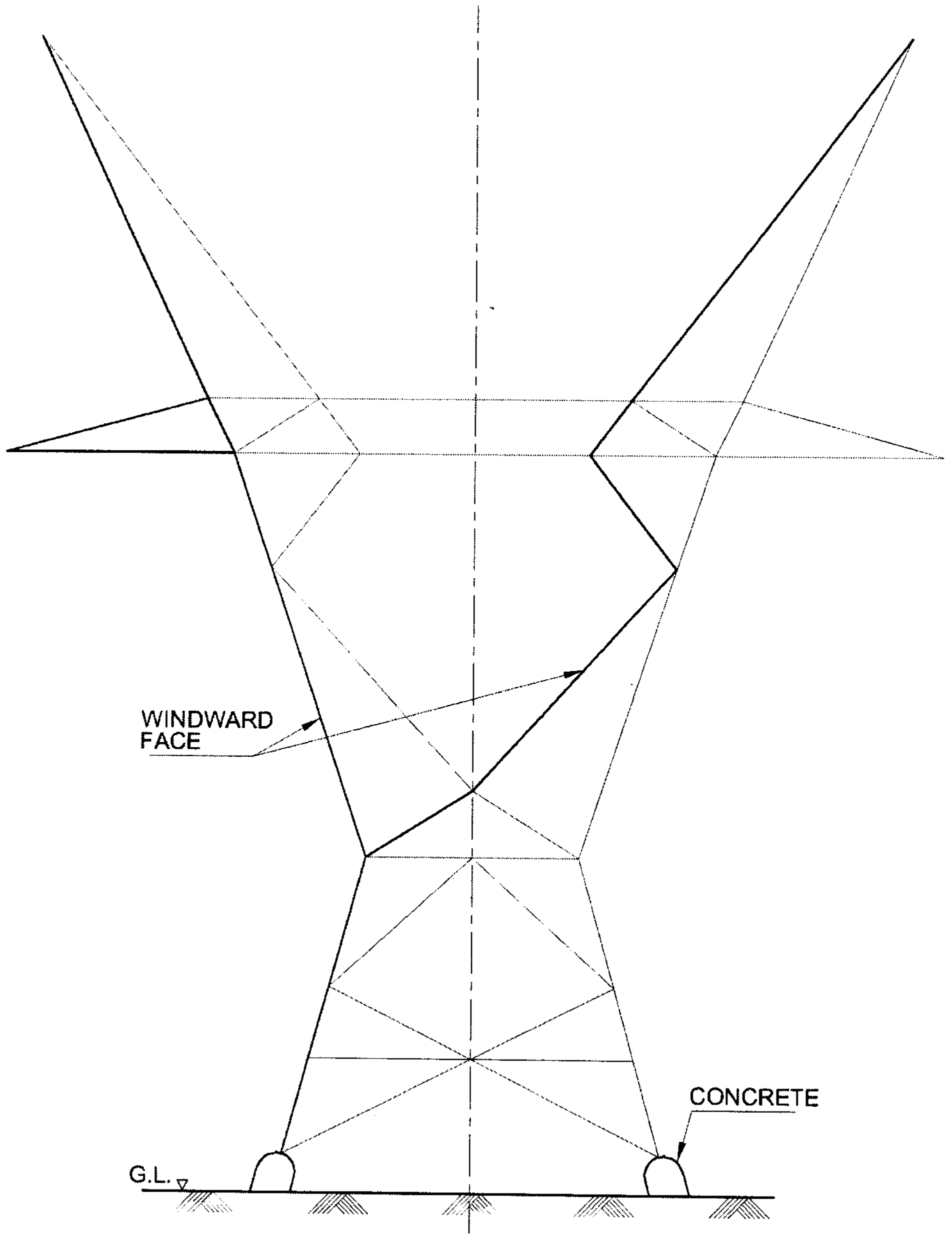


FIG. 3 HORIZONTAL CONFIGURATION TOWER

a) *Climatic loads*, related to the reliability requirements.
b) *Failure containment loads*, related to security requirements.
c) *Construction and maintenance loads*, related to safety requirements.

11.2 Climatic Loads

These are random loads imposed on tower, insulator string, conductor and ground wire/OPGW due to action of wind on transmission line and do not act continuously. Climatic loads shall be determined under the following climatic conditions, whichever is more stringent:

a) 100 percent design wind pressure at everyday temperature, [(Pd) for transverse wind and (P_d* $\sin^2\Omega$) for oblique wind],
b) 75 percent design wind pressure at everyday temperature, or
c) 36 percent design wind pressure at minimum temperature.

NOTES

1 Criterion (b) is to be adopted for all towers under security condition.

2 Criterion (c) is normally not crucial for tangent tower but shall be checked for angle or dead-end towers, particularly for short spans.

Table 7 Values of Gust Response Factor (G_c) for Conductor and Ground Wire/OPGW

(*Clause* 9.2)

Sl No.	Terrain Category	Height Above Ground	Values of G_c for Ruling Span						
			Up to 200 mm	300 mm	400 mm	500 mm	600 mm	700 mm	800 mm and above
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
i)	1	Up to 10	1.70	1.65	1.60	1.56	1.53	1.50	1.47
		20	1.90	1.87	1.83	1.79	1 75	1.70	1.66
		40	2.10	2.04	2.00	1.95	1.90	1.85	1.80
		60	2.24	2.18	2.12	2.07	2.02	1.96	1.90
		80	2.35	2.25	2.18	2.13	2.10	2.06	2.03
ii)	2	Up to 10	1.83	1.78	1.73	1.69	1.65	1.60	1.55
		20	2.12	2.04	1.95	1.88	1.84	1.80	1.80
		40	2.34	2.27	2.20	2.13	2.08	2.05	2.02
		60	2.55	2.46	2.37	2.28	2.23	2.20	2.17
		80	2.09	2.56	2.48	2.41	2.36	2.32	2.28
iii)	3	Up to 10	2.05	1.98	1.93	1.88	1.83	1.77	1.73
		20	2.44	2.35	2.25	2.15	2.10	2.06	2.03
		40	2.76	2.67	2.58	2.49	2.42	2.38	2.34
		60	2.97	2.87	2.77	2.67	2.60	2.56	2.52
		80	3.19	3.04	2.93	2.85	2.78	2.73	2.69

NOTE — Intermediate values may be linearly interpolated.

11.3 Failure Containment Loads

These loads comprise of,

a) anti-cascading loads;
b) torsional and longitudinal loads; and
c) narrow front wind loads.

11.3.1 *Anti-Cascading Loads*

Cascade failure may be caused by failure of items such as insulators, hardware, joints, failures of major components such as towers, foundations, conductor due to defective material or workmanship or from climatic overloads or sometimes from casual events such as misdirected aircraft, avalanches, sabotage, etc. The security measures adopted for containing cascade failures in the line is to provide angle towers at specific intervals which shall be checked for anti-cascading loads (*see* **14**).

11.3.2 *Torsional and Longitudinal Loads*

These loads are caused by breakage of conductors) and/ or ground wire/OPGW. All the towers shall be designed for these loads for the number of conductor(s) and/or ground wire/OPGW considered broken according to **16**.

11.3.2.1 The mechanical tension of conductor/ground wire/OPGW is the tension corresponding to 100 percent design wind pressure at every day temperature or 36 percent design wind pressure at minimum temperature after accounting for drag coefficient and gust response factor.

11.3.3 *Narrow Front Wind Loads*

Only suspension towers are to be designed under this condition. These loads are caused by higher wind velocity in narrow width acting on tower and insulator and no wind is considered acting on wires under this condition.

11.4 Construction and Maintenance Loads

These are loads imposed on towers during construction and maintenance of transmission lines.

12 COMPUTATIONS OF LOADS

12.1 Transverse Loads

Transverse loads shall be computed for reliability, security and safety requirements.

12.1.1 *Reliability Requirements*

These loads shall be calculated as follows:

a) Wind action on tower structures, conductors, ground wire/OPGWs and insulator strings computed according to **9.1**, **9.2** and **9.3** respectively for both the climatic condi-tions specified in **11.2**.
b) Component of mechanical tension F_{wd} of conductor and ground wire/OPGW due to wind computed as per **11.3.2.1**.

Thus, total transverse load

$$= (a) + (b) = F_{wt} + F_{wc} + F_{wi} + F_{wd}$$

where F_{wc}, F_{wi} and F_{wd} are to be applied on all conductors/ground wire/OPGW points and F_{wt} to be applied on tower at ground wire/OPGW peak and cross arm levels and at any one convenient level between bottom cross arm and ground level for normal tower. In case of tower with extensions, one more application level shall be taken at top end of extension.

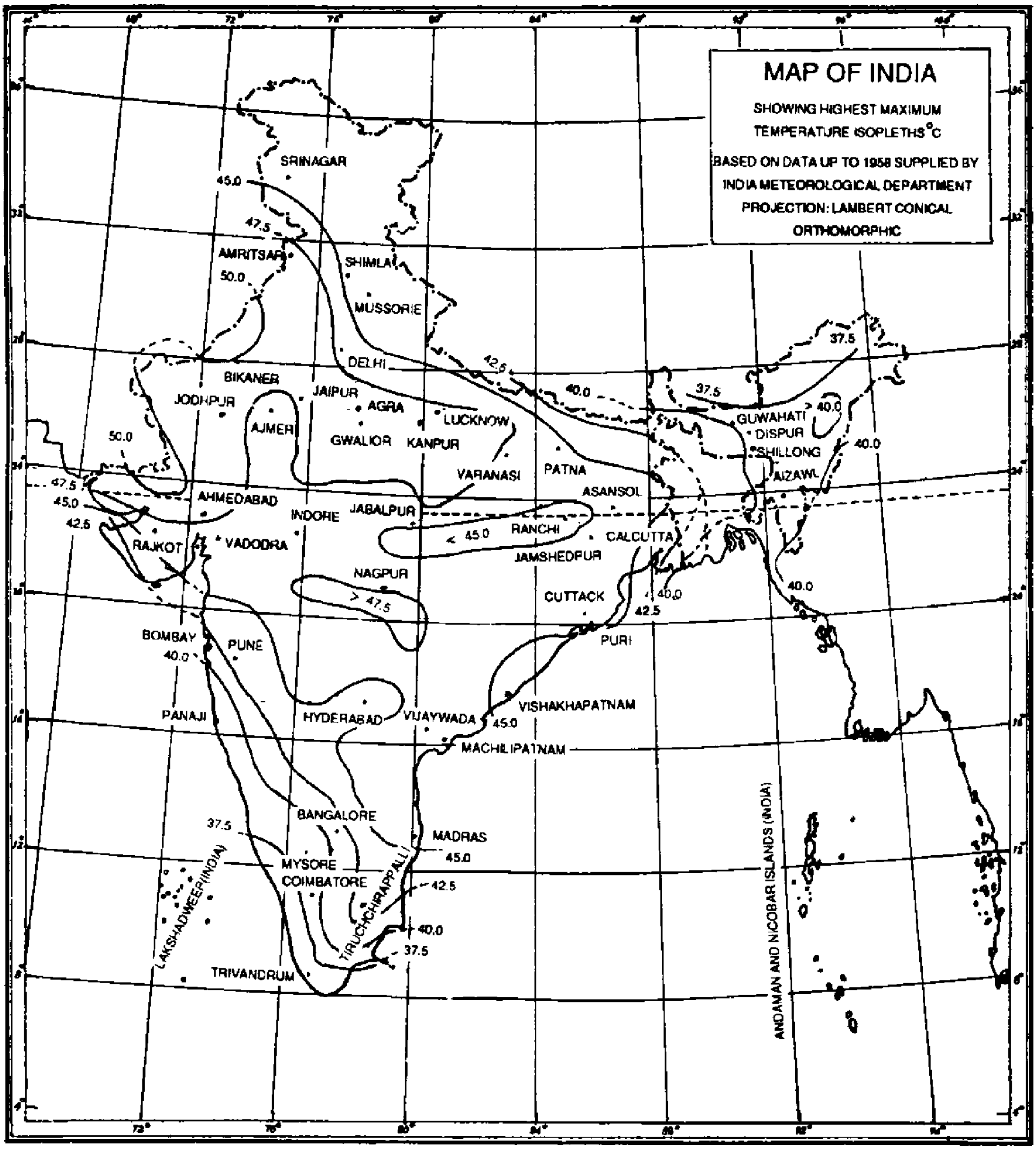
12.1.2 *Security Requirements*

These loads shall be taken as under.

12.1.2.1 *Security requirements under broken wire condition*

a) *Suspension towers:*

1) Transverse loads due to wind action on tower structures, conductors, ground wire/OPGWs and insulators shall be corresponding to 75 percent of full wind pressure at everyday temperature.



Based upon Survey of India Outline map printed in 1987.
The territorial waters of India extend into the sea to a distance of twelve nautical miles measured from the appropriate base line.
Responsibility for the correctness of internal details shown on the map rests with the publisher.

FIG. 4 CHART SHOWING HIGHEST MAXIMUM TEMPERATURE ISOPLETHS

2) Transverse loads due to line deviation shall be based on component of mechanical tension of conductors and ground wire/OPGWs corresponding to everyday temperature and 75 percent of full wind pressure. For broken wire spans the component shall be corresponding to 50 percent mechanical tension of conductor and 100 percent mechanical tension of ground wire/OPGW corresponding to 75 percent of full wind pressure at everyday temperature.

b) *Tension and dead end towers:*

1) Transverse loads due to wind action on tower structure, conductors, ground wire/OPGWs and insulators shall be computed as per **12.1.1** (a). 60 percent wind span shall be considered for broken wire and 100 percent

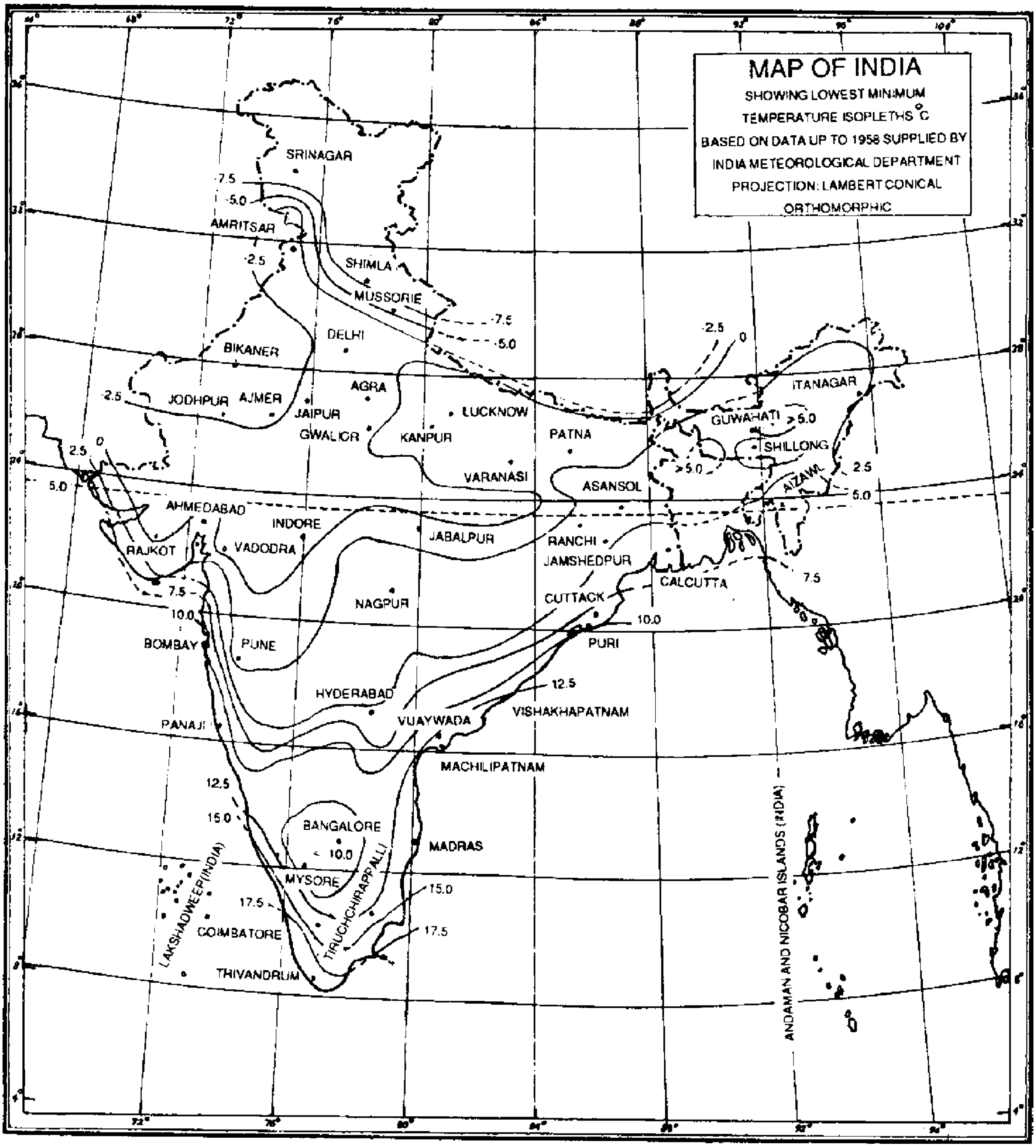


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FIG. 5 CHART SHOWING LOWEST MINIMUM TEMPERATURE ISOPLETHS

wind span for intact span condition.

2) Transverse loads due to line deviation shall be the component of 100 percent mechanical tension of conductor and ground wire/OPGW as defined in **11.3.2.1**.

12.1.2.2 *Narrow front wind requirements*

a) Transverse loads on account of wind on conductors, ground wire/OPGWs shall be taken as nil.

b) Transverse loads due to wind action on tower structure and insulators shall be with a wind speed of 1.5 times basic wind speed. This wind speed is to be considered as reference wind speed (V_R). Wind load shall be calculated as prescribed in **9.1**, but value of G_T would be 1.00.

c) Transverse loads due to line deviation shall

be based on component of mechanical tension of conductors and ground wire/OPGWs corresponding to everyday temperature and nil wind condition.

12.1.3 *Safety Requirements*

Transverse loads on account of wind on tower structures, conductors, ground wire/OPGWs, and insulators shall be taken as nil for normal and broken wire conditions. Transverse loads due to mechanical tension of conductors and ground wire/OPGW at everyday temperature and nil wind condition on account of line deviation shall be taken for both normal and broken wire conditions.

12.2 Vertical Loads

Vertical loads shall be computed for reliability, security and safety requirements.

12.2.1 *Reliability Requirements*

These loads consist of,

a) loads due to weight of conductors/ground wire/OPGW based on design weight span, weight of insulator strings and accessories; and
b) self weight of tower structure up to point/level under consideration.

The effective weight of the conductor/ground-wire should be corresponding to the weight span on the tower. The weight span is the horizontal distance between the lowest points of the conductor/ground wire/OPGW on the two spans adjacent to the tower under consideration. The lowest point is defined as the point at which the tangent to the sag curve or to the sag curve produced, is horizontal.

12.2.2 *Security Requirements*

12.2.2.1 *Security requirements under broken wire condition*

These shall be taken as,

a) same as in **12.2.1** (a) except that the load due to weight of conductor/ground wire/OPGW shall be considered as 60 percent of weight span; and
b) same as in **12.2.1** (b).

12.2.2.2 *Narrow front wind condition*

These shall be taken as:

a) same as in **12.2.1** (a); and
b) same as in **12.2.1** (b).

12.2.3 *Safety Requirements*

These loads shall comprise of,

a) loads as computed in **12.2.2**;
b) load of 1 500 N considered acting at each cross arm, as a provision of weight of lineman with tools;
c) load of 3 500 N considered acting at the tip of cross arms up to 220 kV and 5 000 N for 400 kV and higher voltage for design of cross arms; and
d) following erection loads at lifting points, for 400 kV and higher voltage, assumed as acting at locations specified below:

Tension Tower with	*Vertical Load* N	*Distance, from the Tip of Cross Arm* mm
Twin bundle conductor	10 000	600
Triple/Quadruple bundle conductor	20 000	1 000
Hex bundle conductor	30 000	1 000
Octa bundle conductor	40 000	1 000

All bracing and redundant members of the towers which are horizontal or inclined up to 15° from horizontal shall be designed to withstand ultimate vertical loads of 1 500 N considered acting at centre independent of all other loads.

12.3 Longitudinal Loads

Longitudinal loads shall be computed for reliability, security and safety requirements.

12.3.1 *Reliability Requirements*

These loads shall be taken as follows:

a) Longitudinal load for deadend towers to be considered corresponding to mechanical tension of conductors and ground wire/OPGW as defined in **11.3.2.1**.
b) Longitudinal loads which might be caused on tension towers by adjacent spans of unequal lengths can be neglected in most cases, as the strength of the supports for longitudinal loads is checked for security requirements and for construction and maintenance requirements.
c) No longitudinal load for suspension and tension towers.
d) Under oblique wind condition component of wind load on tower and wind load on insulator in longitudinal direction for suspension and tension towers shall be considered as described in **9.1** and **9.3**.

12.3.2 *Security Requirements*

These loads shall be taken as follows:

a) For suspension towers, the longitudinal load corresponding to 50 percent of the mechanical tension of conductor and 100 percent of mechanical tension of ground wire/OPGW shall be considered under everyday temperature and 75 percent of full wind pressure.

b) Horizontal loads in longitudinal direction due to component of mechanical tension of conductors and groundwire/OPGW shall be considered under everyday temperature and 75 percent of full wind pressure for broken wire(s). For intact wires these loads shall be considered as nil.

c) For dead end towers, horizontal loads in longitudinal direction due to mechanical tension of conductors and groundwire/OPGW shall be considered under everyday temperature and 75 percent of full wind pressure for intact wires. However, for broken wires these shall be taken as nil.

12.3.3 *Safety Requirements*

These loads shall be taken as under:

a) *For normal conditions* — These loads for tension towers and dead end towers shall be considered as corresponding to mechanical tension of conductor/ground wire/OPGW at every day temperature and no wind. Longitudinal loads due to unequal spans may be neglected.

b) *For broken wire conditions:*

   1) *Suspension towers* — Longitudinal load per sub-conductor and ground wire/ OPGW shall be considered as 10 000 N and 5 000 N, respectively.

   2) *Tension towers* — Longitudinal load equal to twice the sagging tension (sagging tension shall be taken as 50 percent of tension at everyday temperature and no wind) for wires under stringing and 1.5 times the sagging tension for all intact wires (stringing completed).

13 LOADING COMBINATIONS

The loading combinations shall be chosen using the following:

Loading Conditions	*Condition*	*Tempera-ture* Degree	*Wind Pressure*	*Wind Direction* θ°	*Trans-verse Load, Reference to Clause No.*	*Vertical Load, Reference to Clause No.*	*Longitud-inal Load, Refe-rence to Clause No.*	*Remarks*
Reliability	Normal	Everyday	100 percent wind	0°, 30° and 45°	**12.1.1**	**12.2.1**	**12.3.1**	—
	Normal	Minimum	36 percent Wind	0°, 30° and 45°	**12.1.1**	**12.2.1**	**12.3.1**	Required to check only if wire tension is critical in this case
Security	Broken Wire	Everyday	75 percent wind	0°	**12.1.2.1**	**12.2.2.1**	**12.3.2**	—
	Broken Wire	Minimum	36 percent wind	0°	**12.1.2.1**	**12.2.2.1**	**12.3.2**	Required to check only if wire tension is critical in this case
	Narrow Front Wind	Everyday	*See* **6.6/6.9.1/6.12**	0°, 45°, 90°	**12.1.2.2**	**12.2.2.2**	—	Only suspension towers, wind on tower and insulator to consider
Safety (Construction and Mainte-nance)	Normal	Everyday	Nil	—	**12.1.3**	*See* Note	**12.3.3**	—
	Broken Wire	Everyday	Nil	—	**12.1.3**	*See* Note	**12.3.3**	—
Anti-cascading Check	—	Everyday	Nil	—	**14 (a)**	**14** (b)	**14** (c)	Tension Towers to be checked for this condition

NOTE — Vertical loads shall be sum of, a) Vertical loads as per **12.2.2** (a) multiplied by the over load factor of 2.b) Vertical loads as per **12.2.3** (b), **12.2.3** (c) and **12.2.3** (d).

14 ANTI-CASCADING CHECKS

All angle towers shall be checked for the following anti-cascading conditions with all conductors and ground wire/OPGW intact only on one side of the tower:

a) *Transverse loads* — These loads shall be taken under no wind condition for maximum deviation angle.

b) *Vertical loads* — These loads shall be the sum of weight of conductor/ground wire/OPGW as per weight span of intact conductor/ground wire/OPGW, weight of insulator strings and accessories.

c) *Longitudinal loads* — These loads shall be the pull of conductor/ground wire/OPGW at everyday temperature and no wind applied simultaneously at all points on one side with zero degree line deviation.

15 TENSION LIMITS

Conductor/ground wire/OPGW tension at everyday temperature and without external load, should not exceed the following percentage of the ultimate tensile strength of the conductor:

a) Initial unloaded tension : 35 percent
b) Final unloaded tension : 25 percent

provided that the ultimate tension under everyday temperature and 100 percent design wind pressure, or minimum temperature and 36 percent design wind pressure does not exceed 70 percent of the ultimate tensile strength of the conductor/ground wire/OPGW.

NOTE — For 400 kV and higher voltage lines, the final unloaded tension or conductors at everyday temperature shall not exceed 22 percent of the ultimate tensile strength of conductors and 20 percent of the ultimate tensile strength of ground wire/OPGW.

16 BROKEN WIRE CONDITION

The following broken wire conditions shall be assumed in the design of towers:

a) Single circuit towers : Any one phase or ground wire/OPGW broken; whichever is more stringent for a particular member.

b) Double, triple circuit and quadruple circuit towers:

1) Suspension towers : Any one phase or ground wire/OPGW broken; whichever is more stringent for a particular member

2) Small and medium angle towers : Any two phases broken on the same side and same span or any one phase and one ground wire/OPGW broken on the same side and same span whichever combination is more stringent for a particular member

3) Large angle tension towers/ dead end towers : Any three phases broken on the same side and same span or any two of the phases and one ground wire/OPGW broken on the same side and same span; whichever combination constitutes the most stringent condition for a particular member

NOTE — Phase shall mean all the sub-conductors in the case of bundle conductors.

17 STRENGTH FACTORS RELATED TO QUALITY

The design of tower shall be carried out in accordance with the provisions covered in IS 802 (Part 1/Sec 2). However, to account for the reduction in strength due to dimensional tolerance of the structural sections and yield strength of steel used, the following strength factors shall be considered:

a) If steel with minimum guaranteed yield strength is used for fabrication of tower, the estimated loads shall be increased by a factor of 1.02.

b) If steel with minimum guaranteed yield strength is not used for fabrication of tower, the estimated loads shall be increased by a factor of 1.07.

ANNEX A
(*Clause* 2)

LIST OF REFERRED INDIAN STANDARDS

IS No.	*Title*
802 (Part 1/Sec 2)	Code of practice for use of structural steel in overhead transmission line towers and substation structures: Material, loads and design strengths, Section 2 Design strengths (*fourth revision*) (*under print*)
802 (Part 2) : 1978	Fabrication, galvanizing, inspection and packing
802 (Part 3) : 1978	Testing
802 (Part 4)	Requirement for lattice switchyard structures (*under formulation*)
875 (Part 3) : 2014	Code of practice for design loads (other than earthquake) for buildings and structures: Part 3 Wind loads (*second revision*)
1161 : 1998	Steel tubes for structural purposes — Specification (*fourth revision*)
1367 (Part 13) : 1983	Technical supply conditions for threaded steel fasteners: Part 13 Hot-dip galvanized coatings on threaded fasteners (*second revision*)
1573 : 1986	Specification for electroplated coatings of zinc on iron and steel (*second revision*)
2016 : 1967	Specification for plain washers (*first revision*)
2062 : 2011	Hot rolled medium and high tensile structural steel — Specification (*seventh revision*)
3063 : 1994	Fasteners — Single coil rectangular section spring lock washers — Specification
4759 : 1996	Hot-dip zinc coatings on structural steel and other allied products
5613	Code of practice for design, installation and maintenance of overhead power lines
(Part 2/ Sec 1) : 1985	Lines above 11 kV and up to and including 220 kV, Section 1 Design
(Part 2/ Sec 2) : 1985	Lines above 11 kV and up to and including 220 kV, Section 2 Installation and maintenance
5624 : 1993	Foundation bolts — Specification (*first revision*)
6610 : 1971	Heavy washers for steel structures — Specification
6649 : 1985	Specification for hardened and tempered washers for high strength structural bolts and nuts
10238 : 2001	Fasteners — Threaded steel fastener — Step bolts for steel structures (*first revision*)
12427 : 2001	Fasteners — Threaded steel fasteners — Hexagon head transmission tower bolts — Specification (*first revision*)
14394 : 1996	Industrial fasteners — Hexagon nuts of product grade C — Hot-dip galvanized — Specification (Size range M 12 to M 36)

ANNEX B
(*Foreword*)

COMMITTEE COMPOSITION

Structural Engineering and Structural Sections Sectional Committee, CED 7

Organization	*Representatives*
In personal capacity (*Block 2, Flat 2A, Rani Meyyammai Towers, MRC Nagar, RA Puram, Chennai – 600 028*)	Dr V. Kalyanaraman (***Chairman***)
Bengal Engineering & Science University, Howrah	Dr Saibal Kumar Ghosh Dr Subrata Chackraborty (*Alternate*)
Bhillai Institute of Technology, Durg	Dr Mohan Gupta
C. R. Narayana Rao, Chennai	Dr C. N. Srinivasan Shri C. R. Arvind (*Alternate*)
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Central Public Works Department, New Delhi	Shri A. K. Garg Shri Manu Amitabh (*Alternate*)
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Consulting Engineering Services, New Delhi	Shri S. Ghosh Shri S. K. Hazra Chowdhury (*Alternate*)
CSIR-Structural Engineering Research Centre, Chennai	Dr S. J. Mohan Dr G. S. Palani (*Alternate*)
Directorate General of Supplies & Disposals, New Delhi	Shri R. P. Singh
Engineer-In-Chief's Branch, New Delhi	Brig Rajesh Tyagi Col M. S. Deol (*Alternate*)
Engineers India Limited, New Delhi	Shri Vinay Kumar Shri Sudhir Chaturvedi (*Alternate*)
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Gammon India Limited, Mumbai	Shri Vikas C. Rane Shri Mohan V. Jatkar (*Alternate*)
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Geodesic Techniques Pvt Ltd, Bangalore	Shri M. Pradyumna Shrimati Jyoti C. Ubhayakar (*Alternate*)
Hindalco Industries Limited, Mirzapur	Dr J. Mukhopadyay Shri Ajay Kumar Agarwal (*Alternate*)
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Indian Institute of Technology Chennai	Dr S. Arul Jayachandran Dr Rupen Goswami (*Alternate*)
Indian Oil Corporation, Noida	Shri T. Bandyopadhyay Shri P. V. Rajaram (*Alternate*)
Institute of Steel Development & Growth (INSDAG), Kolkata	Shri Arijit Guha Shri P. L. Rao (*Alternate*)
Institution of Engineers (India), Kolkata	Shri S. H. Jain
Larsen & Toubro Limited, Chennai	Shri T. Venkatesh Rao Shrimati M. F. Febin (*Alternate*)
M. N. Dastur & Company Pvt Limited, Kolkata	Shri Pratip Bhattacharya Shri Shuvendu Chatopadhyay (*Alternate*)
MECON Limited, Ranchi	General Manager Shri K. K. De (*Alternate*)

Organization	*Representatives*
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Mumbai Port Trust, Mumbai	SHRIMATI REVATI HARDIKAR SHRI UTTAM MITHARAM SURYAVANSHI (*Alternate*)
Northern Railway, New Delhi	CHIEF ENGINEER
NTPC Ltd, Noida	SHRI S. GHOSH SHRI G. BISWAS (*Alternate*)
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BIS Directorate General	SHRI J. ROY CHOWDHURY, Scientist F and Head (Civil Engg) [Representing Director General (*Ex-officio*)]

Member Secretary
SHRI S. ARUN KUMAR
Scientist C (Civil Engg), BIS

(*Continued from second cover*)

While formulating this Code, practices prevailing in the country in this field have been kept in view. Assistance has been derived from the following publications:

a) Design of Latticed Steel Transmission Structures, ASCE-10-97
b) IEC 60050-826 International Electrotechnical Vocabulary - Part 826: Electrical installations

The composition of the Committee responsible for the formulation of this standard is given in Annex B.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall he rounded off in accordance with IS 2 : 1960 ‘Rules for rounding off numerical values (*revised*)’. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

This Indian Standard has been developed from Doc No.: CED 07 (7850).

Amendments Issued Since Publication

Amend No.	Date of Issue	Text Affected

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